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M. B. CASTELLOE

THE EFFECT OF SUDDEN CHILLING ON THE HEAT CONDUCTION OF AN IRON BAR

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THE EFFECT OF SUDDEN CHILLING ON THE HEAT CONDUCTION OF AN IRON BAR.

By

MARK BAILEY CASTELLOE

A Thesis Submitted for the Degree of

BACHELOR OF ARTS

UNIVERSITY OF WISCONSIN

1911

6881145

There is current among blacksmiths, mechanics and iron workers in general a curious belief to the effect that if an iron rod held in the hand is heated red hot at one end and this end then suddenly chilled by plunging it into water, the heat will be driven to the other end so as to be plainly felt by the hand. Since this has appeared in print at various times and has been held for a long time, it seems of sufficient importance to demand experimental investigation — and probable refutation.

An attempt was made to find some account of a previous investigation of this matter, but careful search through various scientific and technical journals, Science Abstracts, and a number of text books on heat and conduction failed to show any mention of previous work on this subject.

The reason given for the occurrence of such a phenomena is unknown. It might be supposed, however, that the shock of the sudden cooling might in some manner cause a wave of heat to pass up to the other end of the rod and so raise the temperature. But this rise in temperature would have to be very rapid and of appreciable magnitude in order to be perceptible to the hand, which is not sensitive enough in general to be able to judge a small rise in temperature very accurately unless it is quite rapid.

According to present theory, heat is a form of energy and the result of heating any portion of matter is the addition of energy. This energy is absorbed in the form of an increase in the kinetic energy of the molecules, which are assumed to be in constant vibration, the velocity with which they vibrate varying with their temperature. If one portion of the body is at a higher temperature than the rest the molecules then will be vibrating faster than the others. In this movement, however, they are constantly striking against other molecules and with their greater velocity they naturally give the others an added impetus, and so the energy, which is really heat, is diffused or conducted throughout the various parts of the body.

According to this, therefore, it will at once be seen that there should be no heating of the other end of the iron bar or other material. For, if the heated end is suddenly cooled, that will result in a marked decrease in the velocity with which the molecules are moving, in that portion, and the other parts cannot therefore receive any added energy but in reality must give up some of their own, and so there will be a cooling of the other parts instead of a heating.

To put this fact to actual experimental test, two iron rods exactly equal in size and length were placed parallel to each other and held in this position by strips of asbestos board. By heating these rods together and

cooling one, and using the other as a standard of comparison, it could be easily determined whether there had been any increase or decrease in temperature.

To compare the two temperatures, a thermo-couple was made of copper and constantin wire, the junction being fused together. One junction was placed in a small hole in the upper end of one rod and the other in a similar hole in the other. If there occurs any difference in temperature between the two junctions, a current will flow and by putting a galvanometer in the circuit this can be detected.

Several experiments were made with these rods but no very decisive results were obtained, so a new arrangement was set up. (See Sketch). The new rods were longer and heavier than the others, being 35.36 cm. long and 1.270 cm. in diameter. Four thermo-couples were used instead of one, placed at equal distances along the rods and connected to four double switches (See diagram) in such a way that each one could be separately connected to the galvanometer. This made it possible to compare the temperature changes at four different points in the rods and so discover any variations that might occur in the results due to distance from the source of heat.

Various methods for heating the rods were tried, the main object being to get some means by which both rods might be heated equally to a temperature sufficiently high

to give satisfactory results. Heating with a gas flame proved to be out of the question because of the great variation in the amount of heat supplied. It also took too long a time to get the rods hot enough. Putting the ends of the rods in melted lead was successful as far as equal heating was concerned, but they could not be gotten hot enough. An attempt was made to use copper instead of lead, but it proved to be too difficult to melt the copper. The method finally adopted was the kryptol resister furnace. which when run by a 220 volt alternating current with from 25 to 35 amperes, gave sufficient heat, and both rods could be heated equally.

The ends of the two rods were placed in the kryptol which heated them red hot for about an inch of their lower extremities. In order to get them equally heated, it was found necessary to heat the furnace up for a few minutes before hand in order to have it assume a uniform temperature. When the rods were removed from the furnace the end of one of them was dipped for about half an inch into cold water. No immediate effect on the galvanometer was apparent, but after a short time, depending on the distance of the thermo couple used from the cooled end, the galvanometer was deflected in a direction indicating a cooling effect, as a piece of ice touched to that junction of the thermo-couple had the same effect. The amount of this deflection varied of course with the temperature and the length of time that the rod was cooled.

SOURCES OF ERROR.

At one time it was thought that a slight heating effect occurred, but after investigation it was discovered that the steam rising when the red hot end of the rod was suddenly thrust into the water sometimes surrounded the thermo-couple and so produced this unusual result. By placing a shield of asbestos around the lower ends of the rods, no further trouble from this source was evident.

In order to avoid the heating effect which would result if a part of the electric current through the furnace should pass across the thermo-couples, several turns of bare copper wire were wound around the upper ends of the rods so that the current would take this path and not heat the thermo-couples. This resulted in the conduction of a large share of the heat from the uncooled rod over to the other, so that the cooling effect was not very strong using the upper two thermo-couples. In order to heat the rods without the copper conductor, it was necessary to get the furnace hot enough so that the current could be turned off and the rods still be heated by the heat already present in the furnace.

The thermo-couples were found to be so sensitive that if the rods were left hanging near the furnace, they would be affected by the heat, the result being similar to that due to steam rising around the thermo-couples.

SPECIFIC RESULTS.

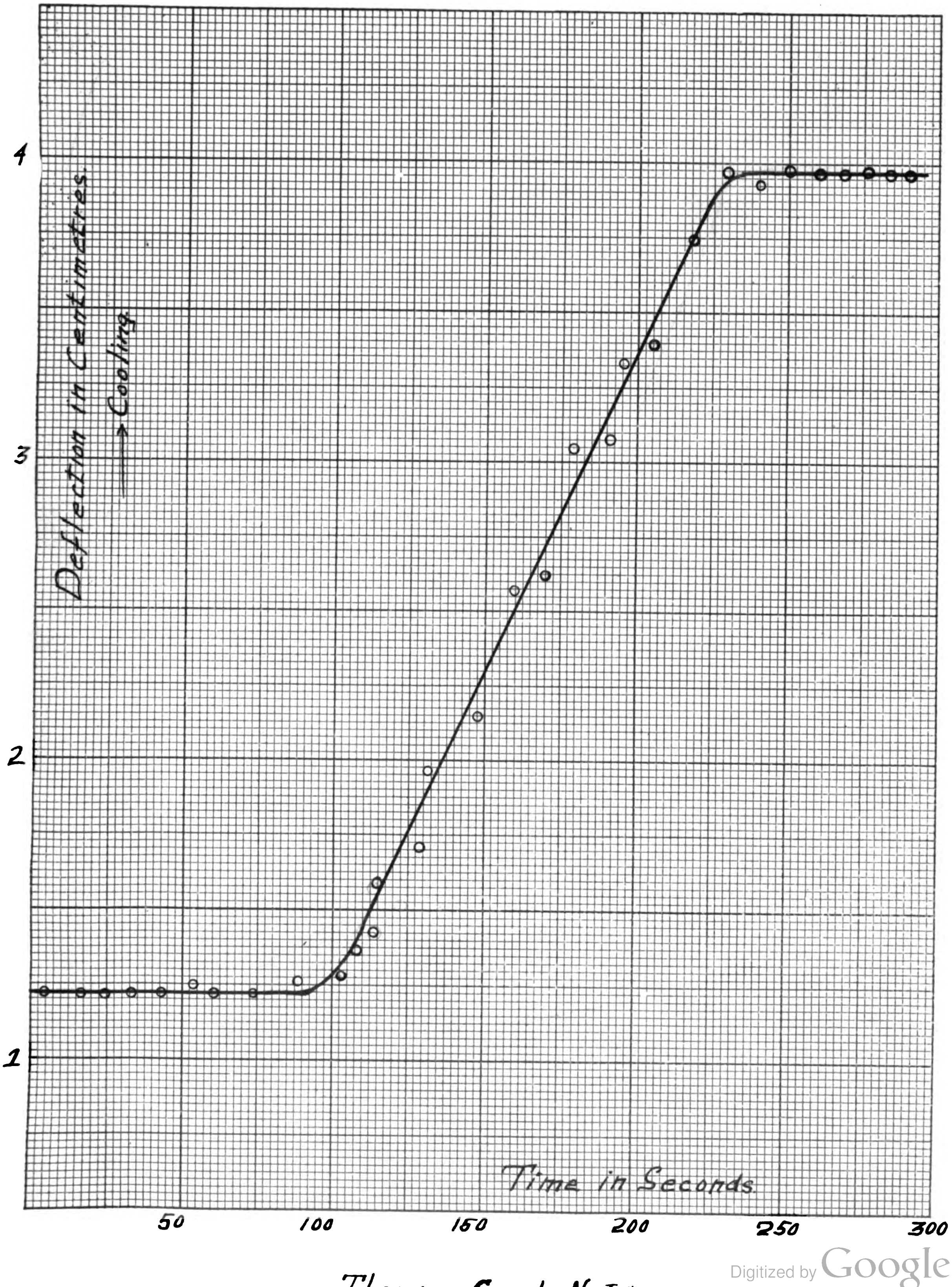
The accompanying plots show some typical variations of the galvanometer deflection due to the cooling of the lower end of one of the rods. The rod was cooled by being plunged for about one centimeter into ice cold water, at the beginning of the indicated time, and the deflection of thegalvanometer was read at the second intervals until it seemed as if a condition of balance had been reached. The plots are marked as to which thermo-couple was used and two typical runs are given for each thermo-couple. The last plot shows the variation in the amount of cooling effect between the different thermo-couples and the variation in the length of time necessary for the cooling effect to become evident, the thermo-couples farthest away taking a great deal more time and giving less change in temperature.

While in some cases there is a drop in the deflection indicating a heating effect, a large number of runs shows that this was not a constant condition but only occurred occasionally and therefore is due to other causes. The actual result is then that in every case, using either rod or any of the thermo-couples, the deflection varied in such a manner as to indicate a decided cooling effect.

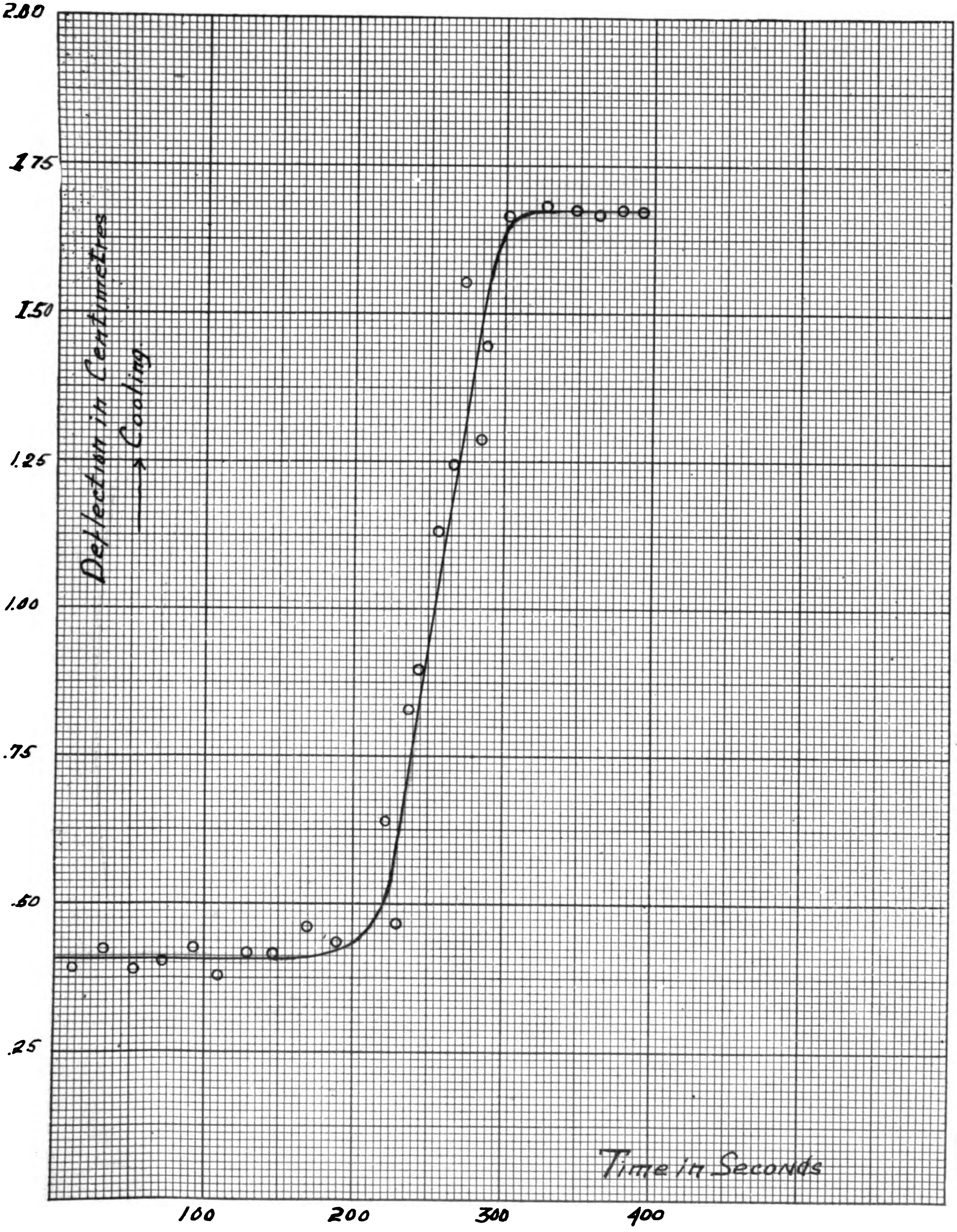
The thermo-couple were found to give about one centimeter deflection per degree difference of temperature

so that it can be seen that the successive deflections measure changes amounting to less than a tenth of a degree. Such a change is of course imperceptible to the hand and therefore if there was any heating effect perceptible to the hand or even many times too small to be felt by the hand, it would surely have been evident.

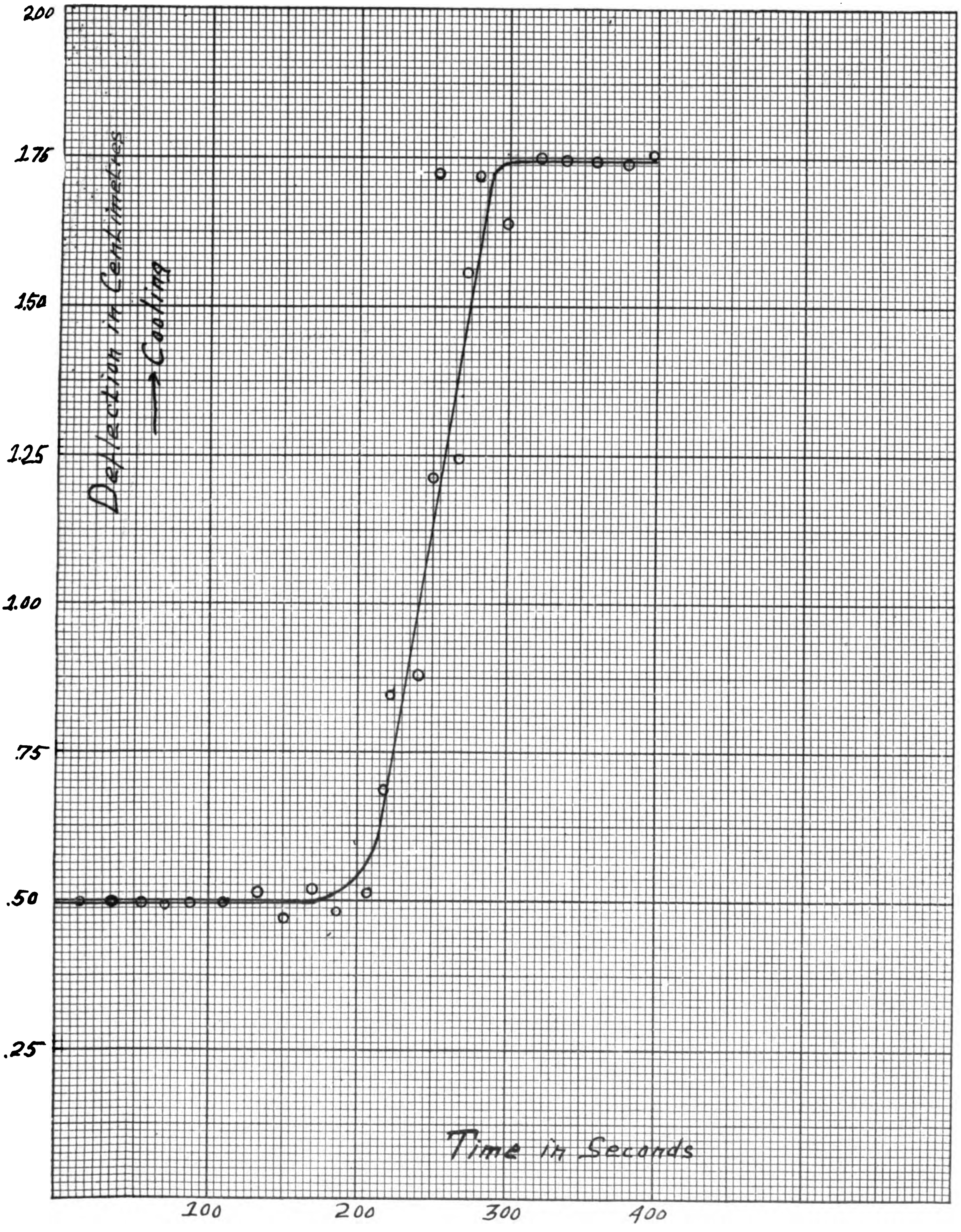
The probable origin of this belief among iron workers is that the heat from the hot end of the rod is just beginning to reach the end held in the hand at about the time the lower end is cooled. The rising of the steam around the rod would tend to increase this effect by causing one to think that the rod was warmer also.



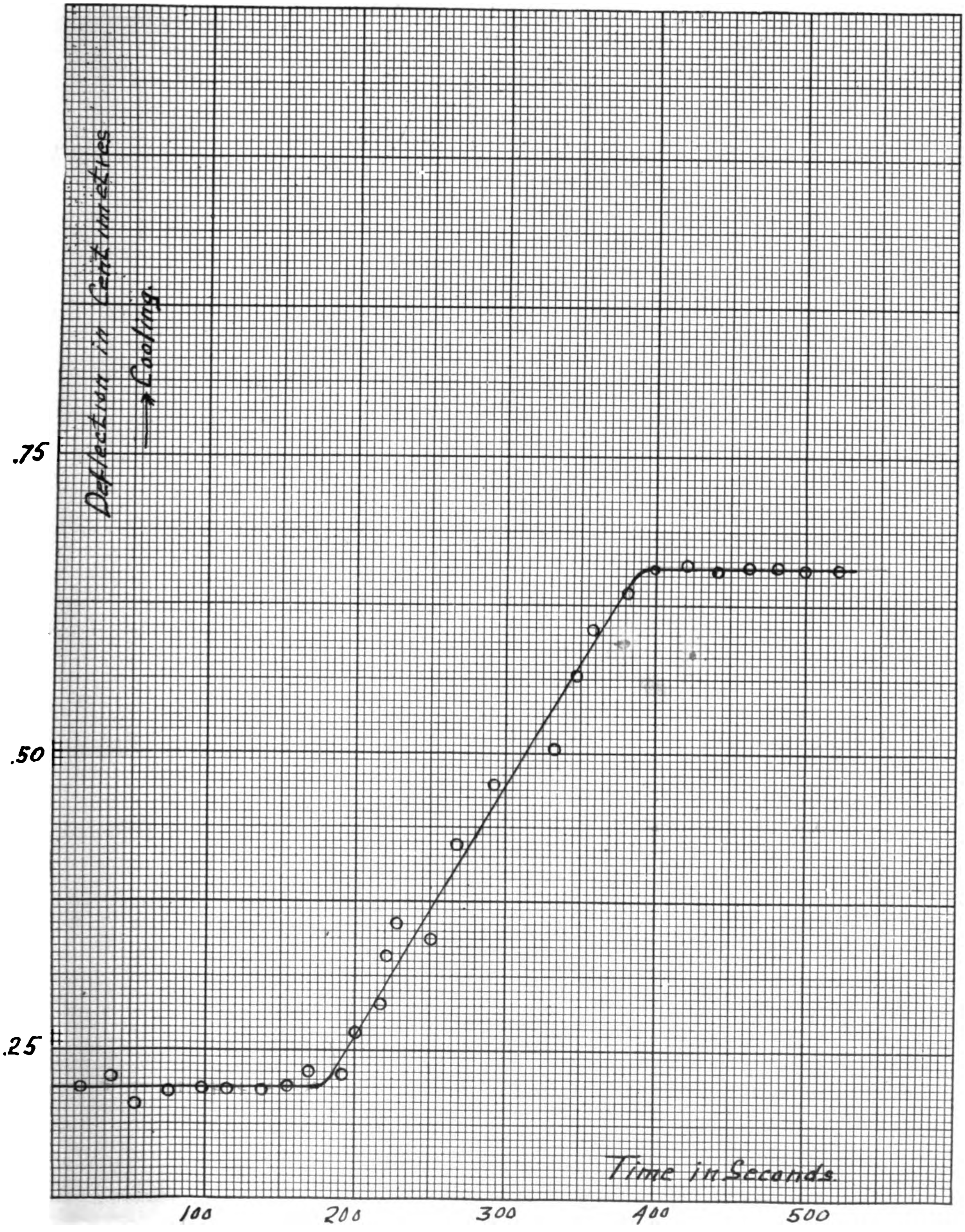
Thermo - Couple No I (4)



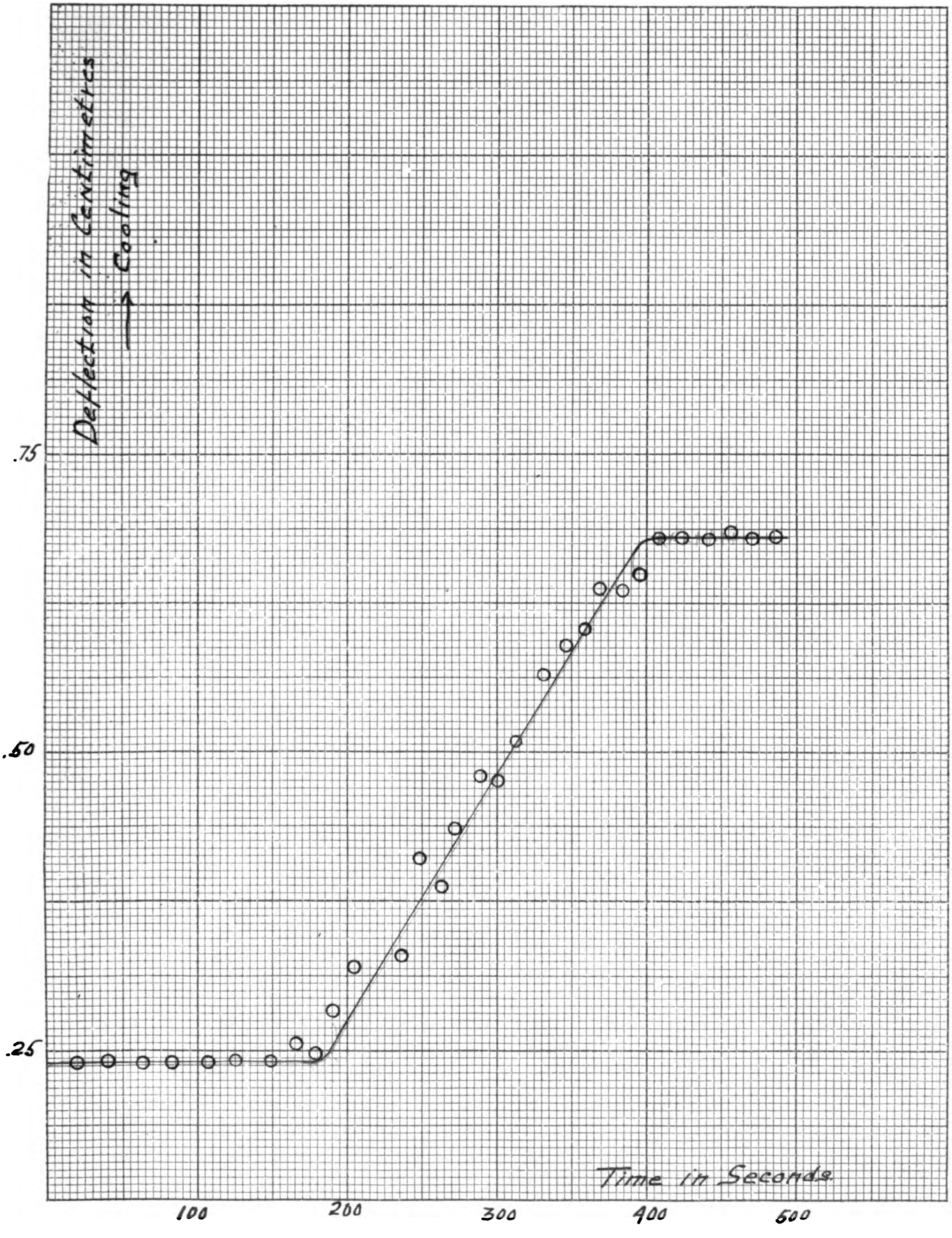
Thermo-Couple No. II (a)



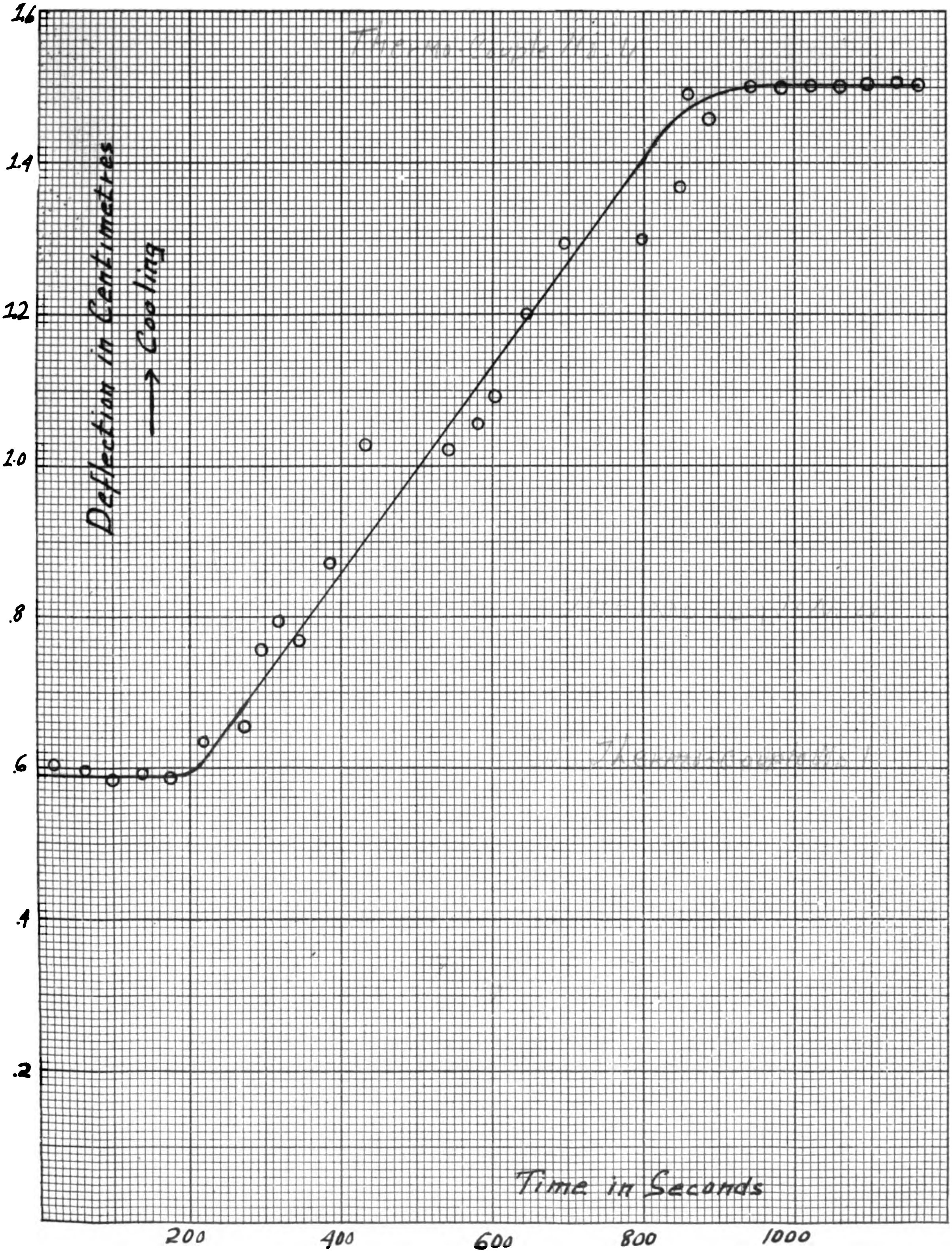
Thermo-Couple No II (b)



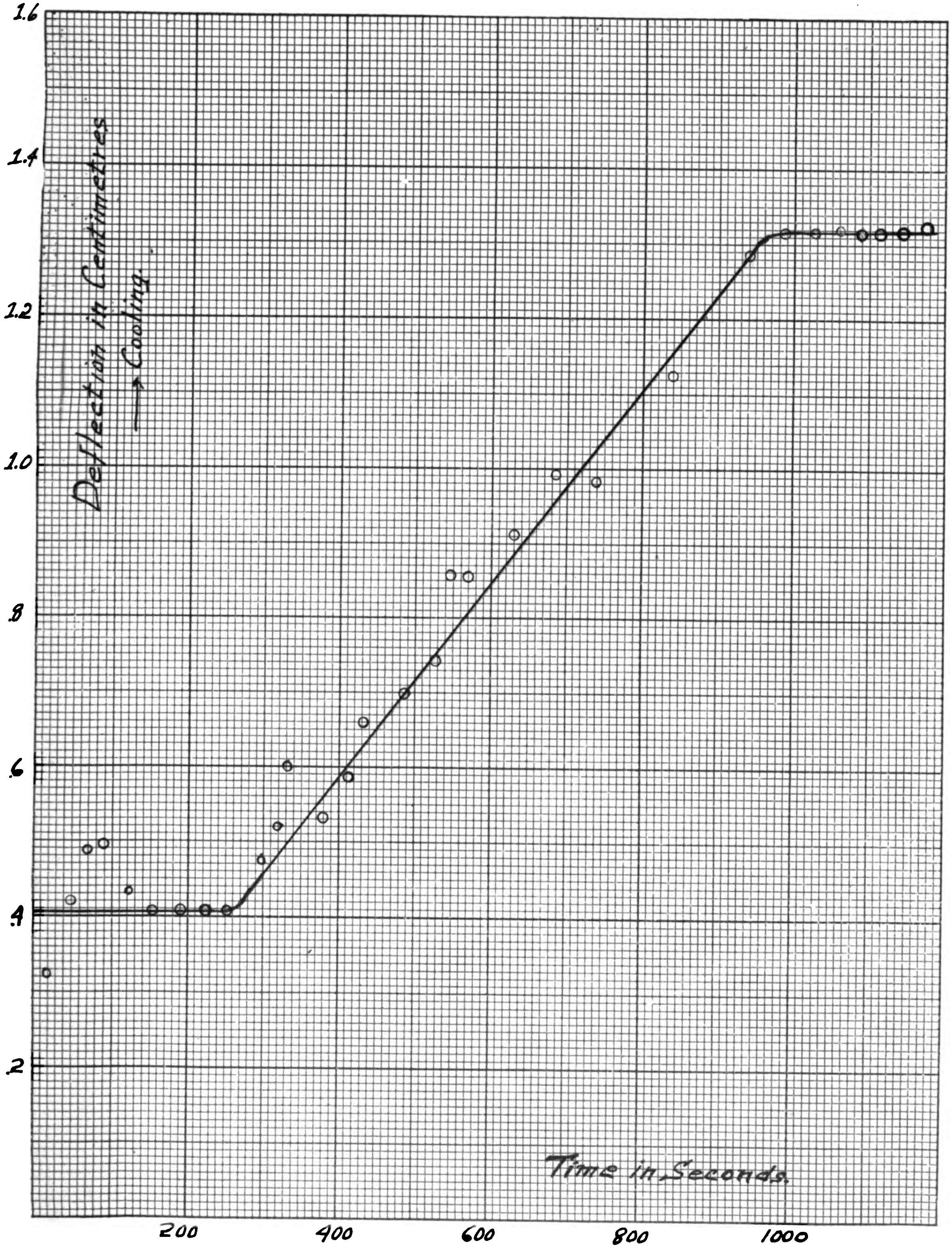
Thermo-Couple No. III (a)



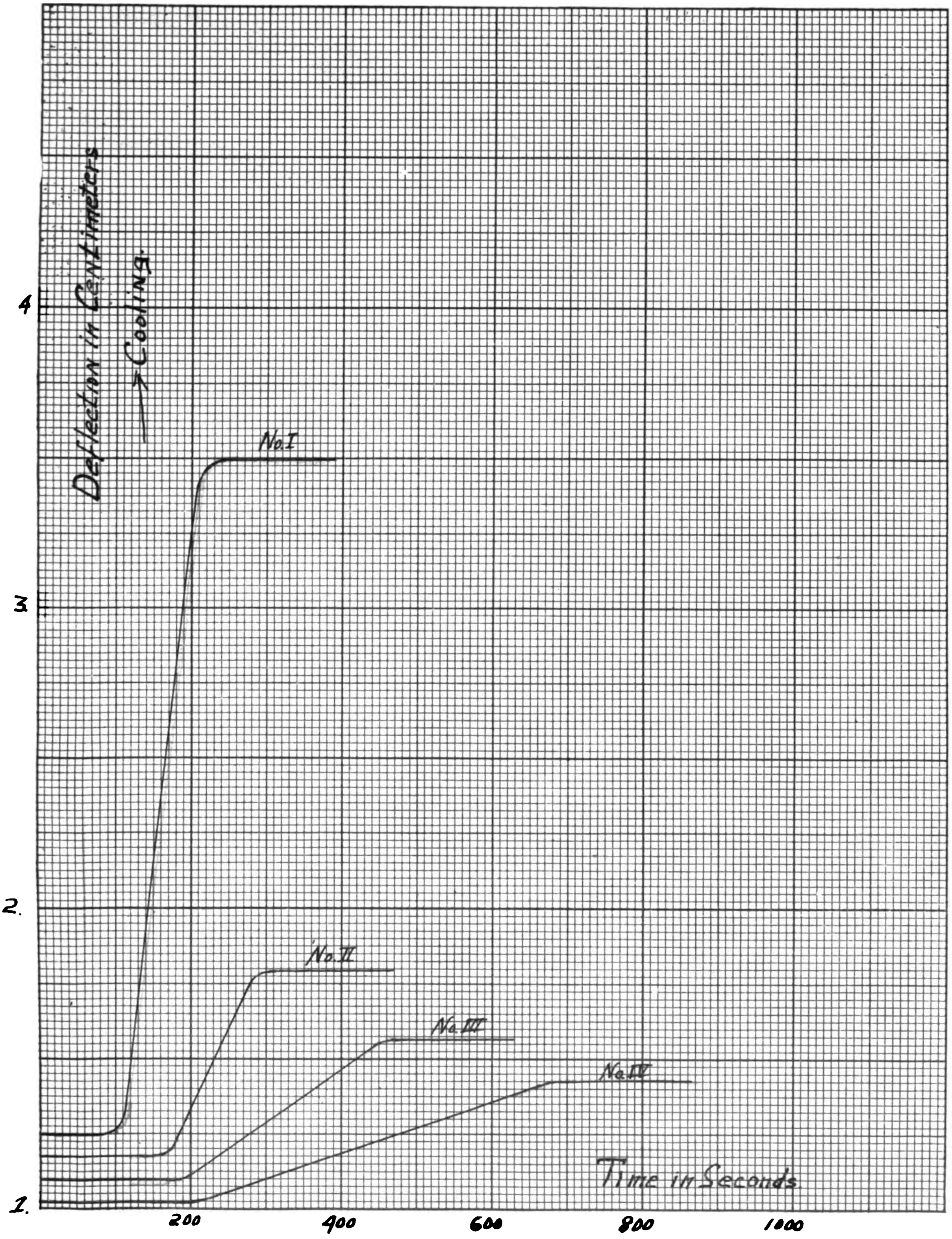
Thermo-Couple No. III(b)



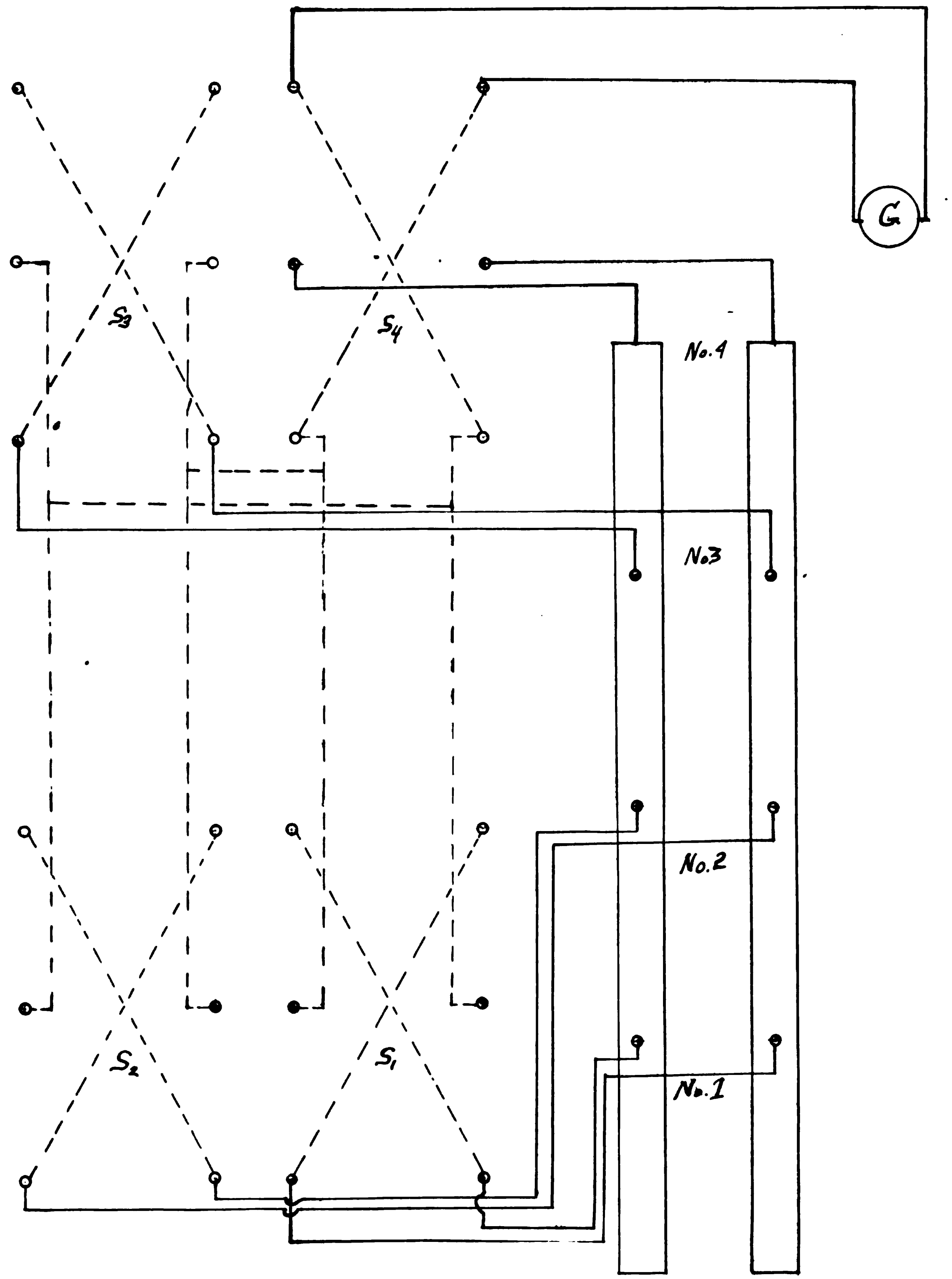
Thermo- Couple No. IV(a)

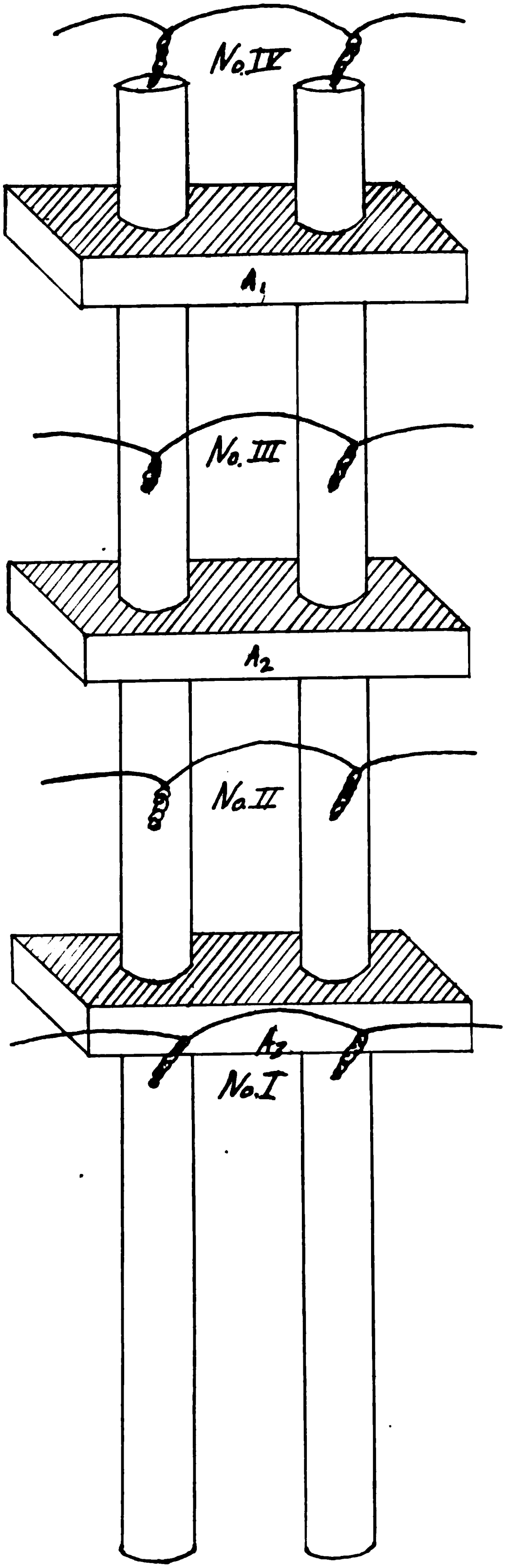


Thermo-Couple No II (b)



Relative Deflections


G
S3
S4
No.4
No.3
No.2
S2
S1
No.1



Sketch of Rods
With Arrangement of Thermo-Couples.

Approved: L. R. Ingersoll

June 15, 1911.

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